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RESEARCH MEMORANDUM

A TRANSONIC INVESTIGATION OF THE STATIC LONGITUDINAL-STABILITY CHARACTERISTICS OF A 45° SWEPTBACK WING-FUSELAGE COMBINATION WITH AND WITHOUT HORIZONTAL TAIL

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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A TRANSONIC INVESTIGATION OF THE STATIC LONGITUDINAL-STABILITY CHARACTERISTICS OF A 45° SWEPTBACK WING-FUSELAGE COMBINATION WITH AND WITHOUT HORIZONTAL TAIL

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SUMMARY

An investigation of the static longitudinal-stability characteristics of a 45° sweptback wing-fuselage configuration has been conducted in the Langley 16-foot transonic tunnel. The wing had an aspect ratio of 3, a taper ratio of 0.2, and NACA 65A004 airfoil sections parallel to the plane of symmetry. Data were obtained for the model with and without a sweptback horizontal tail for an angle-of-attack range from -4° to about 27° and for Mach numbers ranging from 0.80 to 1.05. The Reynolds number varied from 6.0×10^6 to about 8.5×10^6.

The pitching-moment characteristics for this low-taper-ratio wing exhibited only mild instability tendencies for the tail-off configuration for lift-coefficient values increasing from 0.4 to 1.0 as the Mach number increased from 0.80 to 0.98. These instability tendencies were alleviated at all Mach numbers by the addition of a horizontal tail located in the wing-chord plane extended.

INTRODUCTION

The continued trend to higher speeds in aircraft has led to the use of thin wings to improve performance at high transonic and supersonic speeds. Current NACA research investigations include many thin-wing configurations in wing-fuselage combinations suitable for transonic and supersonic flight. Wide variations in the primary wing-geometry parameters, aspect ratio, sweep, and taper ratio, are being covered in these studies. (For example, see refs. 1 to 6.) Results of recent investigations have indicated that the proper selection of wing geometry is an important tool in alleviating the pitch-up tendencies of swept wings. It has been established that, in designing wings for transonic and

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supersonic flight, aspect ratio and sweep must first be made compatible. Reasonably well-defined boundaries for the relationship of these parameters on the basis of longitudinal stability are now available (ref. 5). In many instances, however, drag considerations may permit only an approximation of the desired aspect-ratio—sweep relationship for good longitudinal-stability characteristics. In such cases, variations in wing taper ratio and in horizontal-tail location provide additional means for alleviating pitch-up tendencies.

The 4-percent-thick wing of the present wing-fuselage combination falls slightly beyond the stable region of the high-speed wing-fuselage stability boundary (ref. 5) because of its aspect ratio of 3 and sweep of 45° of the quarter-chord line. The purpose of the present paper, however, is to show that this wing with its low taper ratio of 0.2 in combination with a relatively low tail position will exhibit favorable longitudinal-stability characteristics. This paper presents briefly the longitudinal characteristics which are part of a broad investigation of this configuration in which wing loads, aileron loads, and lateral-control characteristics were also evaluated. Data were obtained for an angle-of-attack range from -4° to about 27° and for Mach numbers ranging from 0.80 to 1.05.

SYMBOLS

b	wing span
c	local wing chord
$\bar{c}$	wing mean aerodynamic chord
C_D	drag coefficient, Drag/qS
C_L	lift coefficient, Lift/qS
C_m	pitching-moment coefficient, about quarter chord of $\bar{c}$, $\text{Pitching moment}/qS\bar{c}$
$\frac{\delta C_m}{\delta i_t}$	horizontal-tail-effectiveness parameter near zero lift
i_t	angle of incidence of horizontal tail
M	free-stream Mach number
P_b	base pressure coefficient, $\frac{p_b - p_o}{q}$
p_b	static pressure at base of model

p_o free-stream static pressure

q free-stream dynamic pressure

R Reynolds number, based on $\bar{c}$

S total wing area

α angle of attack of fuselage center line relative to air flow

$\frac{dC_L}{d\alpha}$ lift-curve slope near zero angle of attack

$\frac{dC_m}{dC_L}$ longitudinal-stability parameter, pitching-moment curve slope near zero lift

APPARATUS

Tunnel

The present investigation was conducted in the Langley 16-foot transonic tunnel, a single-return octagonal slotted-throat wind tunnel. A detailed description of this tunnel is presented in reference 7. As indicated in this reference, the maximum variation of the average Mach number along the test-section center line in the vicinity of the model is about ±0.002.

Model

The wing for the present investigation had NACA 65A004 airfoil sections parallel to the plane of symmetry, 45° sweepback of the quarter-chord line, an aspect ratio of 3, and a taper ratio of 0.2. Coordinates for the NACA 65A004 airfoil section are presented in table I. The wing was mounted in the midwing position on the fuselage and had no geometric incidence, dihedral, or twist. The fuselage consisted of a cylindrical body of revolution having an ogival nose and a slightly boattailed afterbody and was the same fuselage as that described in reference 3. The horizontal tail had an aspect ratio of 4, a taper ratio of 0.6, and NACA 65A006 airfoil sections parallel to the plane of symmetry. Coordinates for the NACA 65A006 airfoil section may be found in reference 8. The ratio of the span of the horizontal tail to the span of the wing was 0.517. The horizontal tail was bolted to the fuselage in the midfuselage position at an angle of incidence of −4° and all gaps were filled and faired smooth. The geometric details of the model are given in figure 1.

Model Support System

A single swept-cantilever strut supported the sting-mounted model for the present tests. This support system, described in detail in reference 9, held the model near the tunnel center line throughout the angle-of-attack range and provided angle-of-attack variations from -5° to 15°. A 10° coupling between the sting and the model extended the upper limit of this angle-of-attack range to 27°.

TESTS

The present investigation consisted of measuring the aerodynamic forces and moments for the tail-off configuration through the available angle-of-attack range (-4° to about 27°) for Mach numbers up to 0.98. Above this Mach number this configuration was tested only to an angle of attack of about 12°. Data were obtained for the tail-on configuration at fewer Mach numbers than for the tail-off configuration. At Mach numbers up to 0.98, the angle-of-attack range for the tail-on configuration was limited by balance capacities to angles of attack considerably lower than that for the tail-off configuration (for example, 17° at 0.98 Mach number).

Forces and moments were measured by a six-component electrical strain-gage balance mounted within the fuselage.

The Reynolds number for the present tests, based on a mean-aerodynamic-chord length of 1.894 feet, ranged from 6.0×10^{6} to about 8.5×10^{6}. The variation of Reynolds number over the speed range is presented in figure 2.

CORRECTIONS AND PRECISION

Force-Data Accuracy

The data presented herein were not adjusted for sting and tunnel-wall effects since these effects are known to be generally negligible up to a Mach number of 1.03. Above this Mach number, as shown in reference 10, wall-reflected disturbances will affect the accuracy of the data, particularly drag coefficient; the values of drag coefficient presented herein for a Mach number of 1.05 are known to be unrealistically high. The accuracy of the force and moment coefficients, based on balance accuracy and repeatability of measurements, is believed to be within the following limits:

C_L . . . . ±0.01
C_D (at low lift coefficients). ±0.002
C_D (at high lift coefficients) . . . . ±0.004
C_m . . . . ±0.003

Angle of Attack

The angles of attack for the present tests, which were corrected for tunnel flow angularity, refer to the angle of the fuselage center line relative to the air flow. The model angles of attack for the tail-off configuration were obtained by adjusting an indicated angle for balance and sting deflection due to aerodynamic load. The balance and sting deflection data were obtained from calibrations using static loads; however, based on repeatability of measurements, the maximum error in angle-of-attack measurements obtained by this method is estimated to be $\pm 0.1^{\circ}$. For the tail-on configuration, however, the model angles of attack relative to the tunnel center line were obtained by use of a pendulum-type strain-gage inclinometer and are estimated to be accurate to within $\pm 0.1^{\circ}$.

Base Pressure

Lift and drag data were adjusted to the condition of free-stream static pressure at the model base. The variations of the base pressure coefficient for each configuration, which were measured by three orifices located 2 inches inside the base of the model, are presented as functions of angle of attack for the Mach numbers of the present investigation in figure 3. Based on repeatability of measurements, the base pressure coefficients are estimated to be accurate to within ±0.01.

RESULTS AND DISCUSSION

The lift, drag, and pitching-moment data for the tail-off configuration are presented in figure 4 for Mach numbers between 0.80 and 1.05 and are compared with the data obtained for the horizontal tail-on configuration in figure 5 for Mach numbers at which tail-on data were obtained. A summary of the effects of Mach number on the aerodynamic characteristics for both tail-off and tail-on configurations is presented in figure 6. The horizontal-tail-effectiveness parameter as a function of Mach number is shown in figure 7.

Both the tail-off and tail-on configurations exhibited linear lift characteristics for lift coefficients at least as high as 0.6 at all Mach numbers (figs. 4(a) and 5(a)). The highest lift coefficient of the present tests (about 1.31) was obtained for the tail-off configuration at an angle of attack of approximately 27.5° and at a Mach number of 0.98. The slope of the lift-coefficient curve $\frac{dC_L}{d\alpha}$ for the tail-off configuration (fig. 6) was about 0.058 at a Mach number of 0.80, increased to a maximum value of 0.070 at a Mach number of about 0.94, and decreased with increased speed.

The pitching-moment-coefficient characteristics for this low-taper-ratio sweptback wing exhibited mild instability tendencies for the tail-off configuration (fig. 4(b)). The lift-coefficient values at which these mild tendencies occurred increased from 0.4 to 1.0 as the Mach number increased from 0.80 to 0.98. Above a Mach number of 0.98, the range of lift coefficients investigated was insufficient to define an unstable break in pitching moment if indeed any existed. With the horizontal tail mounted on the model, the mild instability characteristics were alleviated (fig. 5(b)). Associated with this particular horizontal tail, a stable pitching-moment break occurred at somewhat higher lift coefficients than those at which instability previously occurred for Mach numbers up to 0.94. Because of the mild nature of the unstable pitching-moment breaks and the small range of lift coefficient for which unstable tendencies were indicated for the tail-on configuration, it is believed that the complete configuration would possibly have satisfactory characteristics even on the basis of dynamic stability considerations. This conjecture is further strengthened by the lack of abrupt changes in the longitudinal-stability parameter $\frac{dC_m}{dC_L}$ with Mach number (fig. 6). The shift throughout the Mach number range in the aerodynamic center, represented by the longitudinal-stability parameter, was from -0.07 to -0.17 for the tail-off configuration (fig. 6(b)), constituting 10 percent of the mean aerodynamic chord; the shift was from -0.15 to -0.28 for the tail-on configuration, amounting to 13 percent of the mean aerodynamic chord.

With the horizontal tail mounted at an angle of incidence of -4°, the configuration trimmed at a lift coefficient of about 0.36 ($\alpha \approx 6^\circ$) at low Mach numbers and at a lift coefficient of about 0.22 ($\alpha \approx 4^\circ$) at a Mach number of 1.03. The horizontal-tail-effectiveness parameter $C_{m_{i_t}}$ (which was obtained by assuming the effectiveness of the horizontal tail to be zero at 0° angle of incidence and to be linear at least up to an angle of incidence of -4°) was about 0.015 at low

Mach numbers and reached a maximum of about 0.018 at a Mach number of approximately 0.98 (fig. 7).

CONCLUSIONS

The following conclusions are drawn from a transonic wind-tunnel investigation of a 45° sweptback wing having a taper ratio of 0.2 and NACA 65A004 airfoil sections in combination with a fuselage tested with and without a horizontal tail:

1. The pitching-moment characteristics for this low-taper-ratio sweptback wing exhibited only mild instability tendencies for the tail-off configuration for lift-coefficient values increasing from 0.4 to 1.0 as the Mach number increased from 0.80 to 0.98. With the addition of the horizontal tail at an angle of incidence of -4°, the mild instability characteristics were alleviated.

2. A gradual rearward movement in the location of the aerodynamic center was indicated as Mach number increased through the range tested. The variation was 10 percent of the mean aerodynamic chord for the tail-off configuration and 13 percent of the mean aerodynamic chord for the tail-on configuration.

3. The slope of the lift-coefficient curve for the tail-off configuration increased from about 0.06 at a Mach number of 0.80 to a maximum of about 0.076 at a Mach number of 0.94.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., January 12, 1956.

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TABLE I

COORDINATES FOR THE NACA 65A004

AIRFOIL SECTION

x (percent c)	y (percent c)
0	0
.5	.311
.75	.378
1.25	.481
2.5	.656
5.0	.877
7.5	1.062
10	1.216
15	1.463
20	1.649
25	1.790
30	1.894
35	1.962
40	1.996
45	1.996
50	1.952
55	1.867
60	1.742
65	1.584
70	1.400
75	1.193
80	.966
85	.728
90	.490
95	.249
100	.009

L.E. radius: 0.102 percent c
T.E. radius: 0.010 percent c

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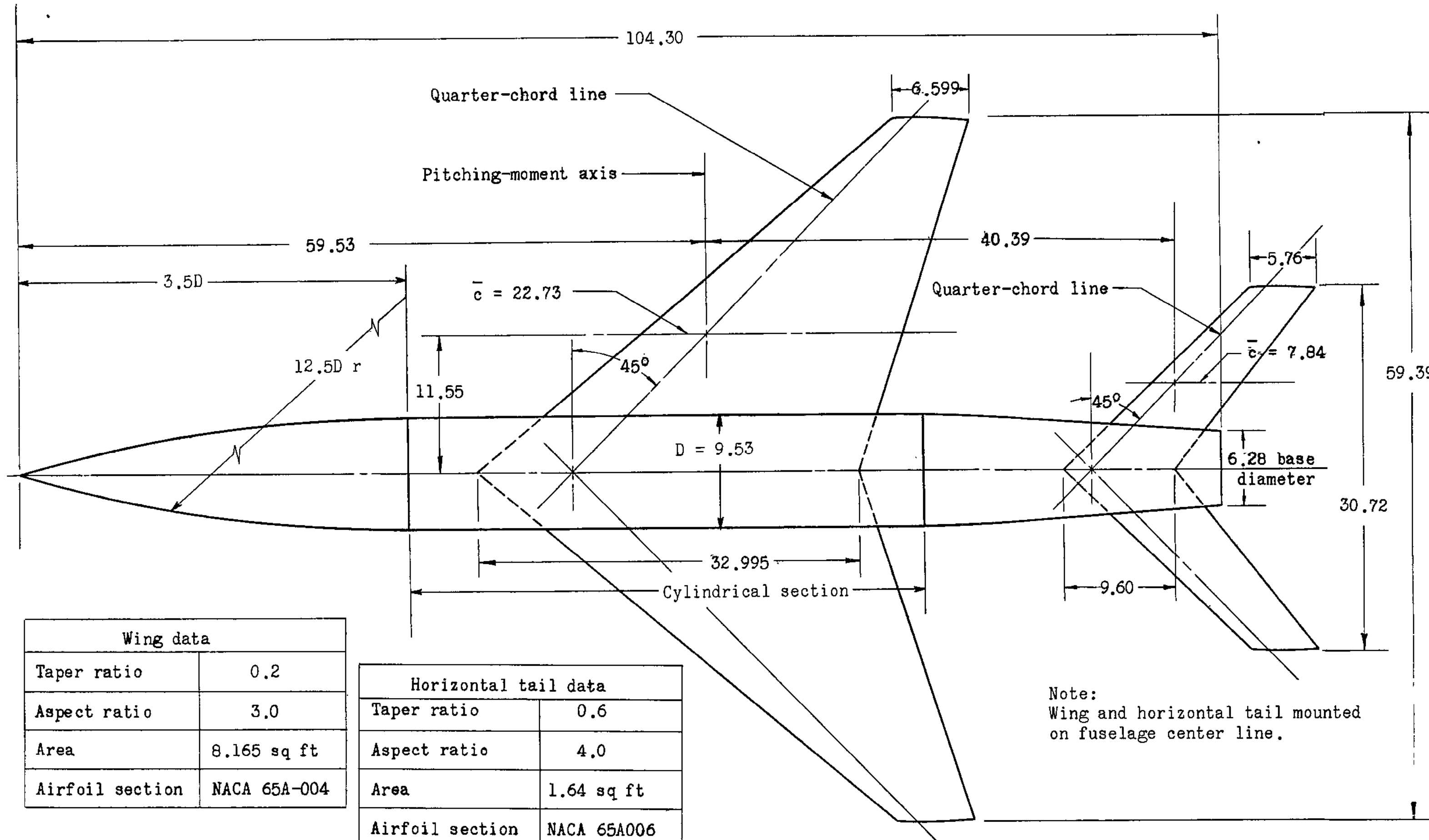

Wing data	
Taper ratio	0.2
Aspect ratio	3.0
Area	8.165 sq ft
Airfoil section	NACA 65A-004

Horizontal tail data	
Taper ratio	0.6
Aspect ratio	4.0
Area	1.64 sq ft
Airfoil section	NACA 65A006
Angle of incidence	-4°

Figure 1.- Dimensional details of model. (All linear dimensions in inches.)

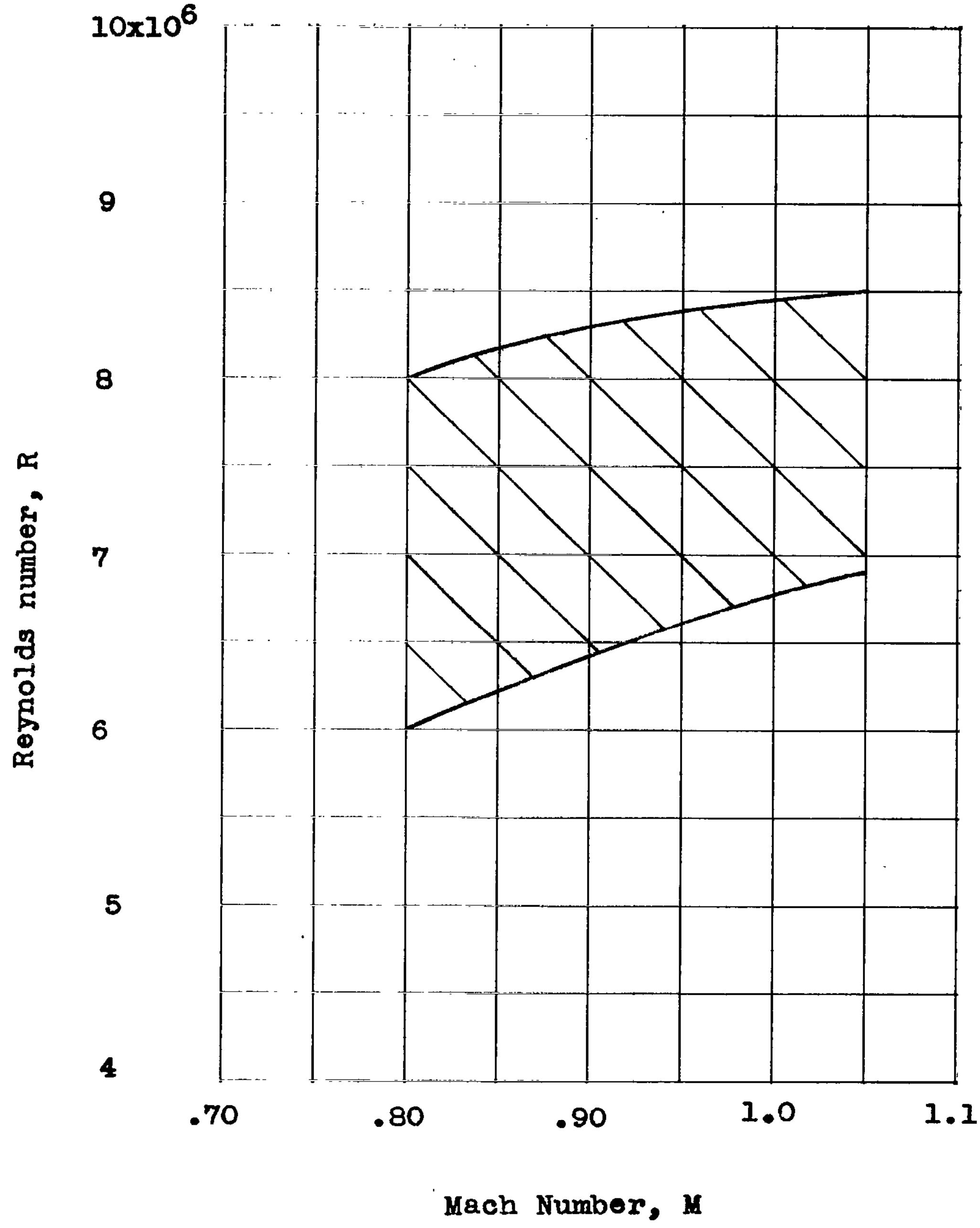

Figure 2.- Variation of Reynolds number (based on mean aerodynamic chord) with Mach number.

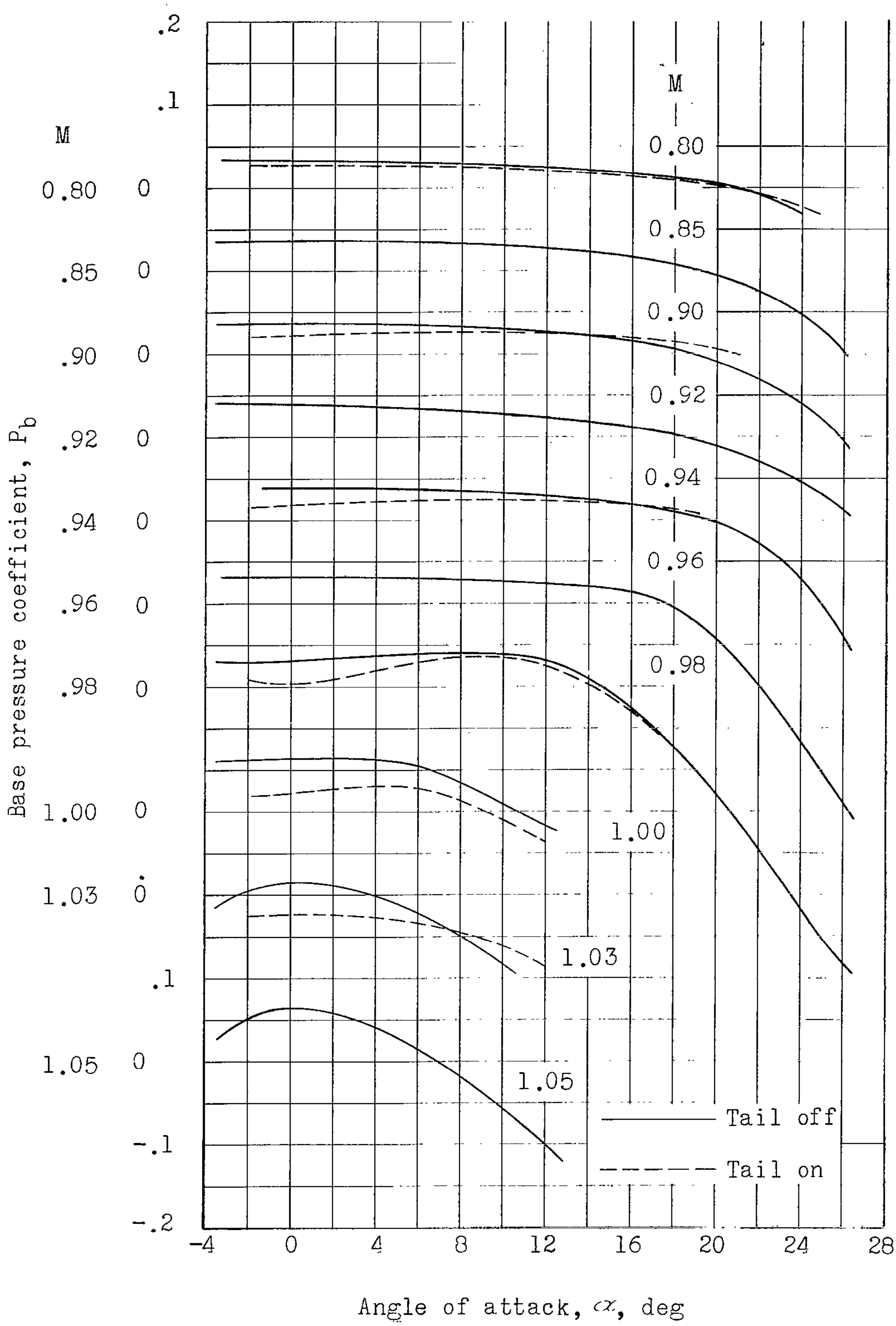

Figure 3.- Variation of base pressure coefficient with angle of attack for all Mach numbers.

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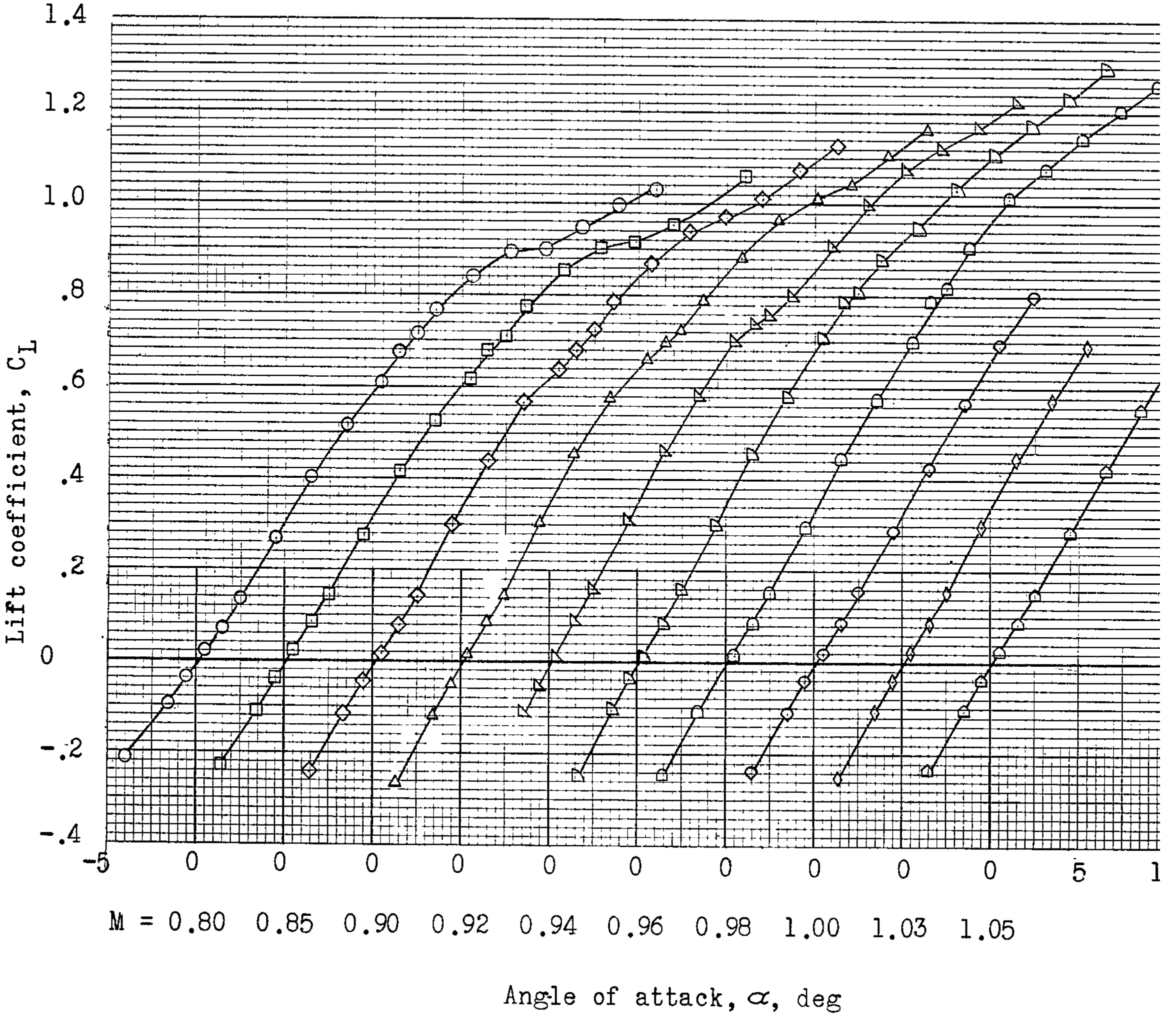
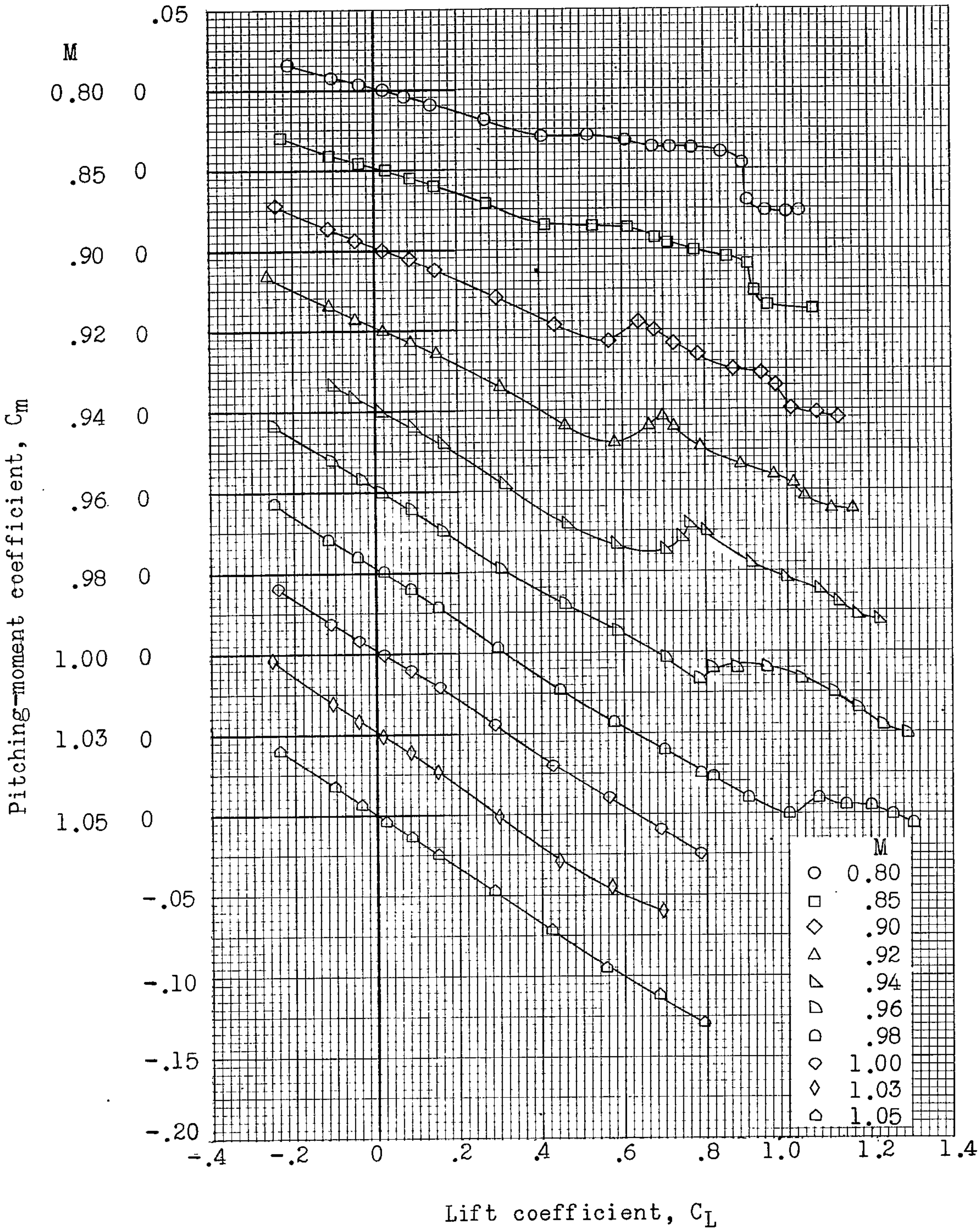


(a) Lift.

Figure 4.- Aerodynamic characteristics of the basic wing-fuselage conf



(b) Pitching moment.

Figure 4.- Continued.

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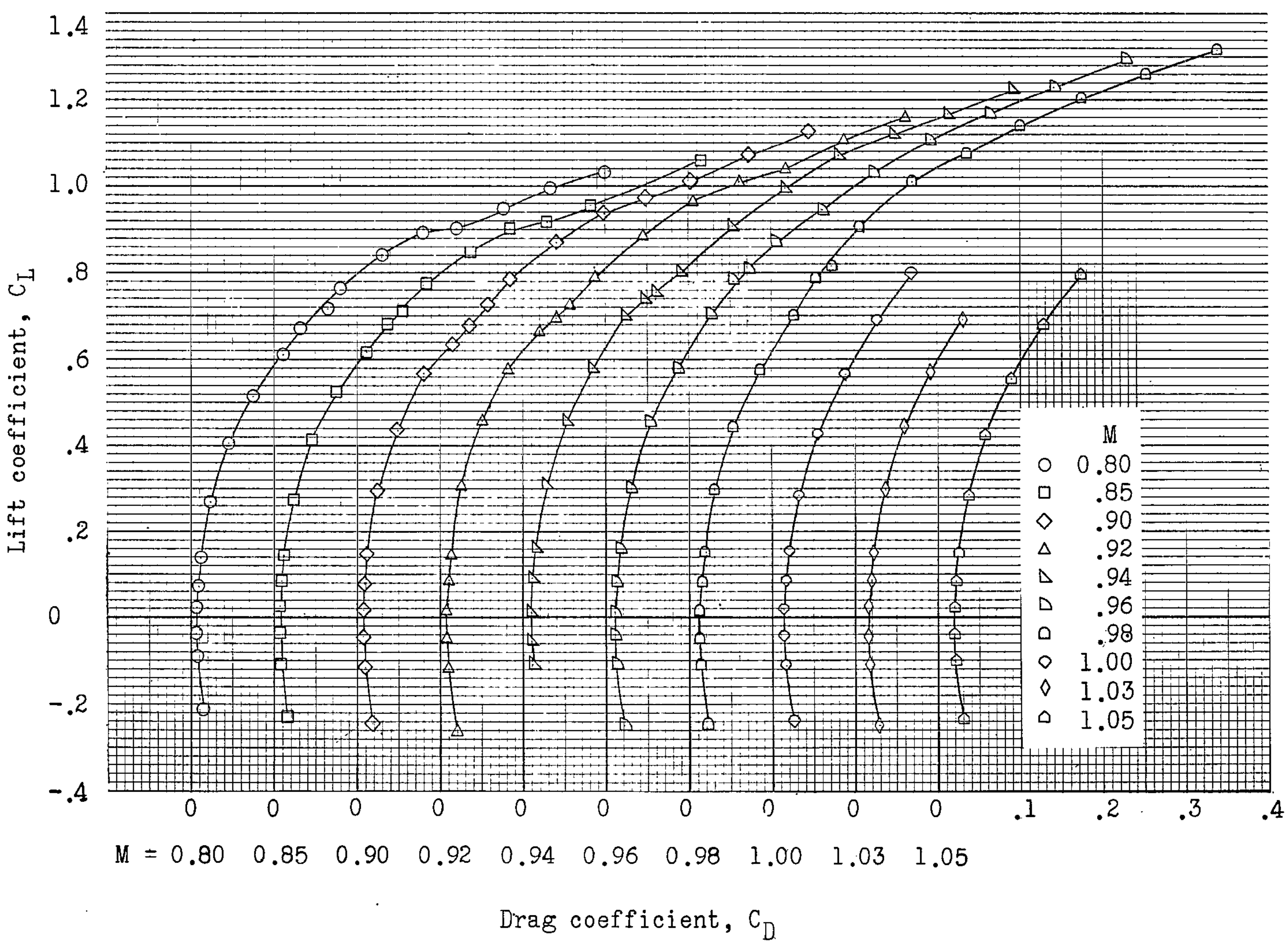

(c) Drag at high lifts.

Figure 4.- Concluded.

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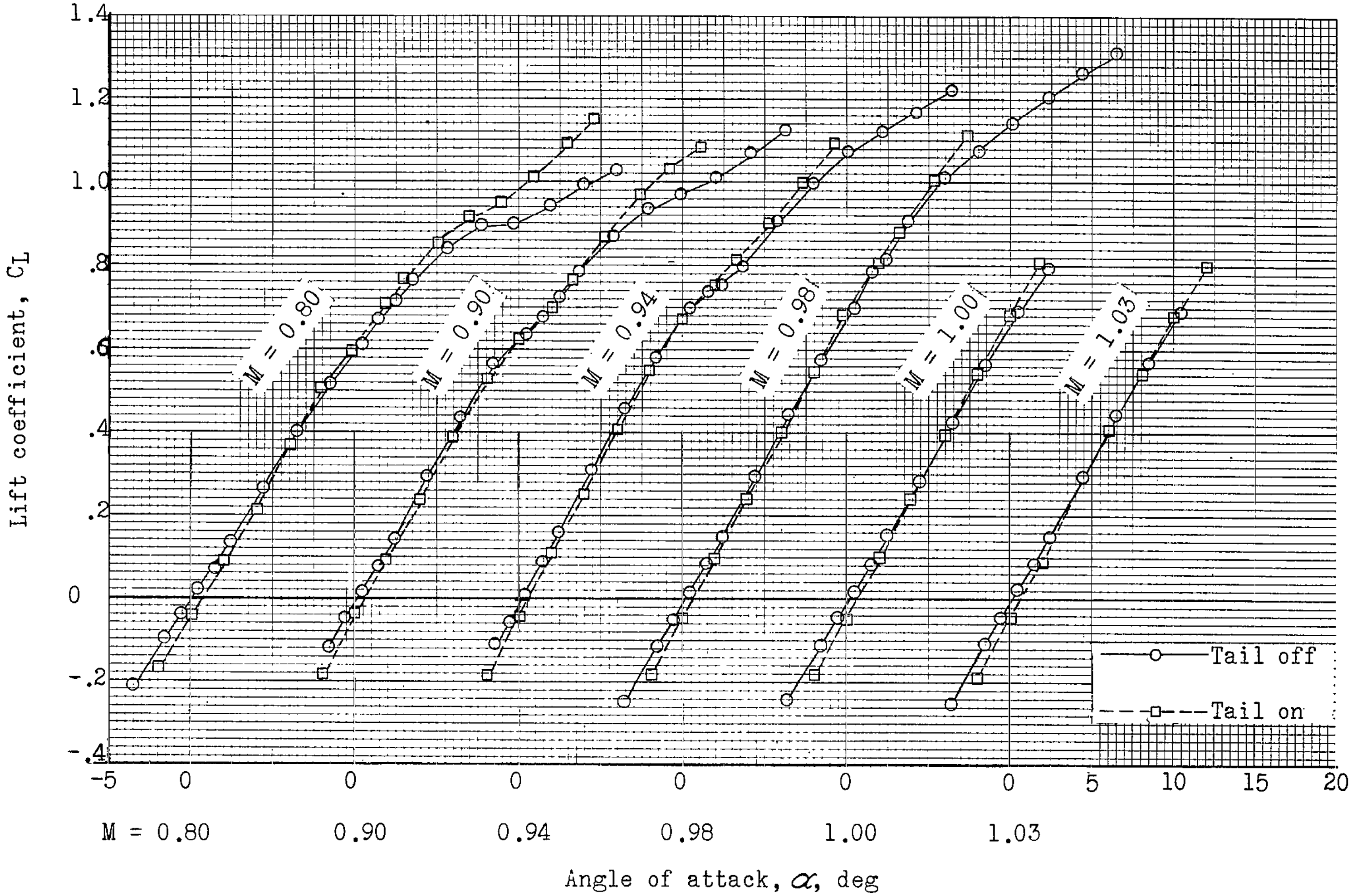

(a) Lift.

Figure 5.- Effect of the addition of a horizontal tail at angle of incidence of -4° on aerodynamic characteristics of basic tail-off configuration.

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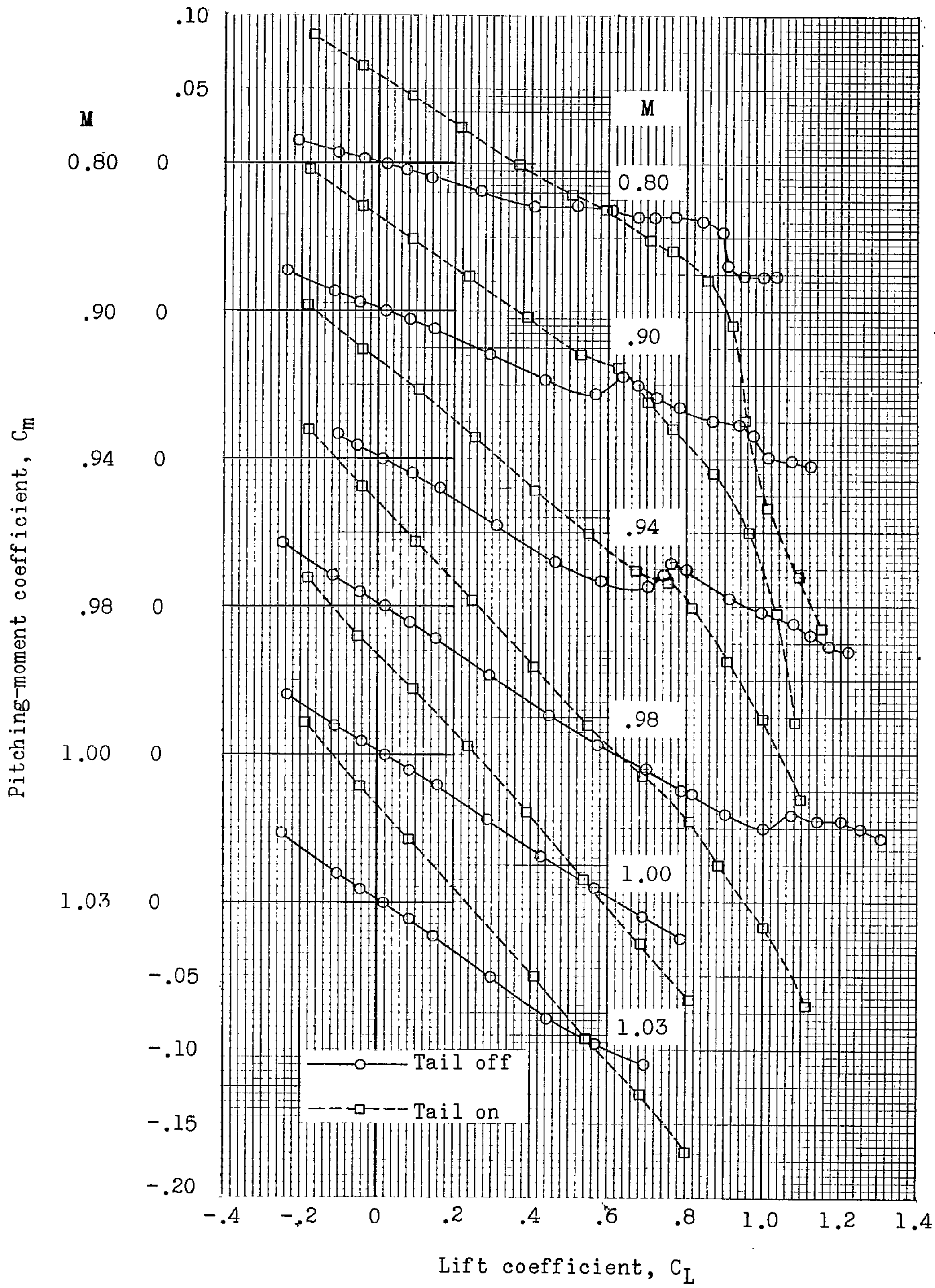

(b) Pitching moment.

Figure 5.- Continued.

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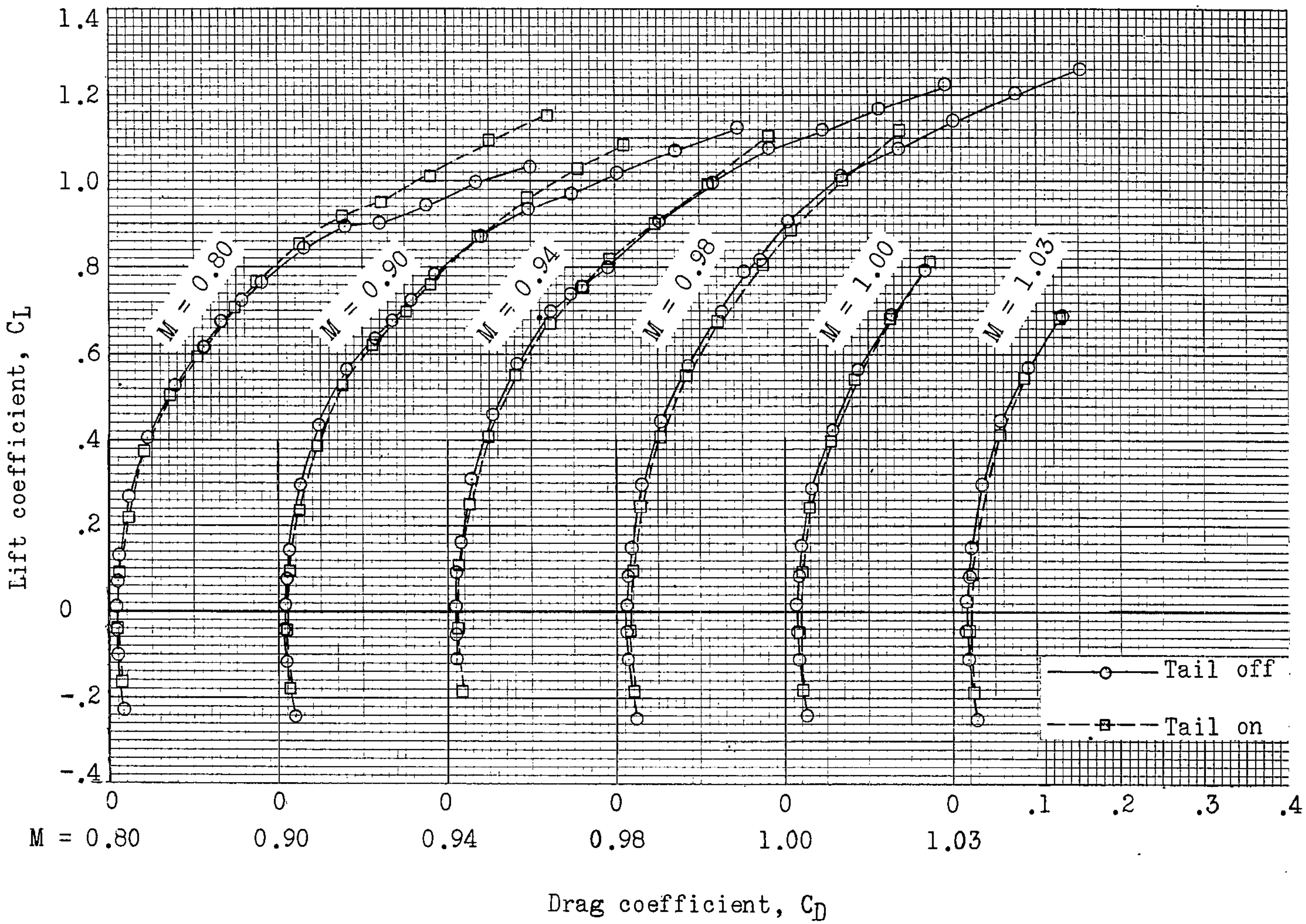

(c) Drag at high lifts.

Figure 5.- Concluded.

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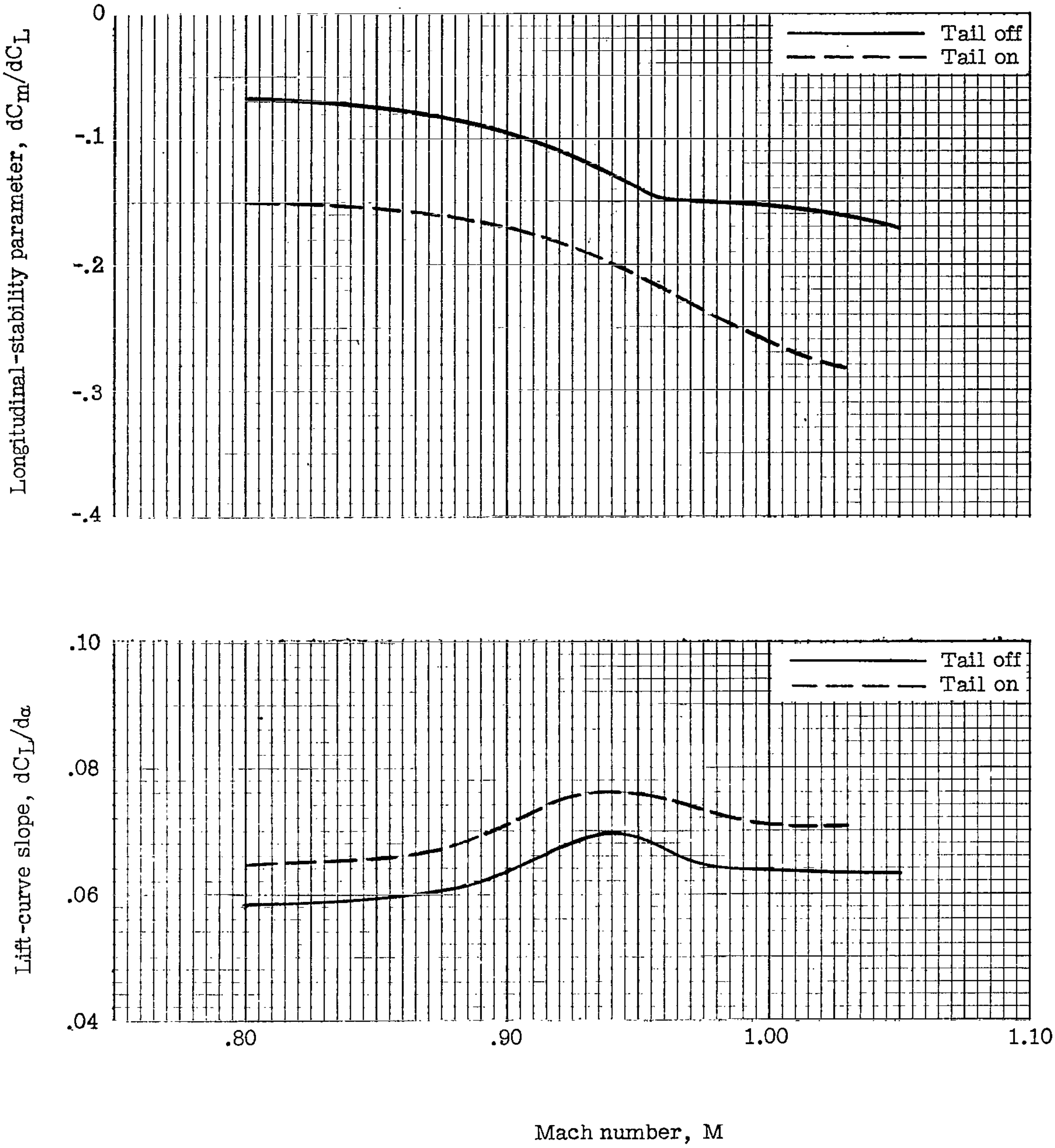

Figure 6.- Longitudinal-stability parameters and lift-curve slopes as functions of Mach number for the tail-off and tail-on configurations.

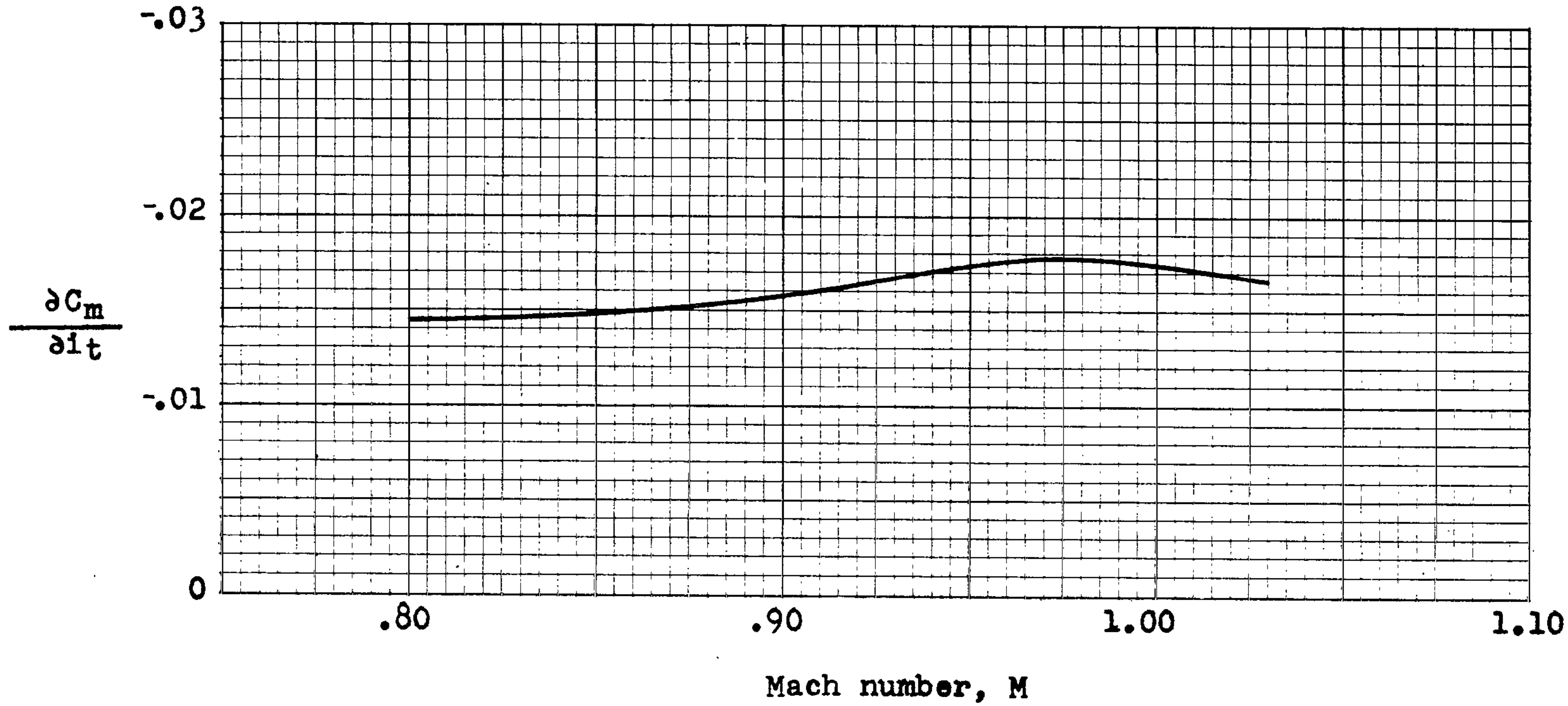

Figure 7.- Horizontal-tail-effectiveness parameter.